Candidate Nutritional Countermeasure to Mitigate Adverse Effects of Spaceflight

Completed Technology Project (2017 - 2019)

Project Introduction

In recent findings, we showed that dried plum (DP) diet conferred complete protection from the rapid bone loss induced by exposure to radiations, including gamma, protons, and High Z-High Energy (HZE) ions. Based on these very promising results on a new potential countermeasure for space radiation tissue damage, we propose to conduct additional studies and analyses, which are critical for moving the potential countermeasure to a higher countermeasure readiness level (CRL) level. We aim to test the DP diet to prevent bone loss induced by simulated spaceflight. This will be achieved by exposing mice to each factor (weightlessness and radiation) alone and combined. Furthermore, we will establish if DP protects other tissues at risk for astronauts, such as the central nervous system.

Anticipated Benefits

Countermeasures that address the combined effects of simulated microgravity and ionizing radiation have not been investigated in bone. Both these factors are inherent to the spaceflight environment and thus, countermeasures must be investigated regarding their protective effect when both are in combination. We sought to evaluate the potentially differing effects of microgravity and ionizing radiation when controlled independently on bone and the two factors in combination. For the purpose of this study, we have used the hindlimb unloading model, in combination with exposure to total body irradiation (132Cs gamma radiation, at 2 Gy dose) as analogs of weightlessness and radiation exposure. The relatively higher dose of radiation (2 Gy) was chosen as a positive control dose to ensure bone loss in rodents to allow for testing DP as a countermeasure for bone loss. We sought to determine if the DP diet prevents simulated-microgravity induced bone loss (HU), as well as if the diet is also effective at preventing simulated spaceflight-induced bone loss (combination of HU+irradiation (IR). To address these questions, we analyzed both cancellous and cortical bone microarchitecture as well as bone quality. Additionally, we aimed to determine if the DP diet had the capacity to protect osteoprogenitors after exposure to simulated microgravity, an essential part in the healthy maintenance of the skeletal tissue.

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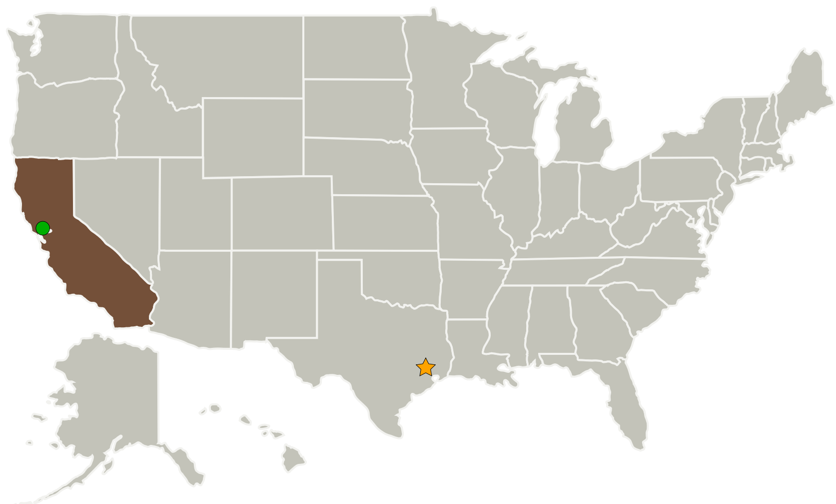
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, Texas
●Ames Research Center(ARC)	Supporting Organization	NASA Center	Moffett Field, California

Primary U.S. Work Locations
California

Project Transitions

January 2017: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Project Manager:

Peter Norsk

Principal Investigator:

Ann-sofie Schreurs

Co-Investigators:

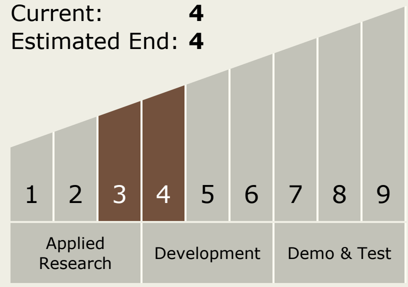
Ruth K Globus
Candice Tahimic

December 2019: Closed out

Closeout Summary: In this study, we investigated the bone protective potential of Dried Plum (DP) against independent and combined effects of simulated microgravity (Hindlimb Unloading, HU) and ionizing radiation (IR) on the microarchitecture and mechanical properties of skeletal tissue. A diet supplemented with DP prevented most of the simulated spaceflight-induced damages to both the appendicular (i.e., tibia) and axial (i.e., vertebrae) skeleton. When mice were fed the control diet, a relatively high dose (2 Gy) of low-LET (linear energy transfer) gamma radiation exclusively decreased the bone volume fraction (BV/TV) and trabecular separation (Tb.Sp) of cancellous tissue in the tibia. Based on our results, cancellous bone loss was caused by a thinning, not a decrease in the number, of existing trabeculae, which overall expanded the space between trabeculae. Hindlimb unloading (HU) for 14 days caused bone loss within both cancellous and cortical regions of the tibia and the L4 vertebrae. HU also led to reduced compressive strength of the vertebral body. The independent effects of HU and radiation (IR) remained of similar magnitude in each tissue compartment when mice were exposed to HU and IR simultaneously. Regardless of the treatment (with one exception, Ct.Th proximal tibia), consumption of the dried plum diet prevented detrimental skeletal changes. Mice fed the control diet and exposed solely to IR displayed a 20% decrement in percent bone volume and a 7% increase in the Tb.Sp of the tibia's cancellous region relative to the sham control. These parameters were unaffected by HU alone. HU groups exhibited a lesser 11% decrement in trabecular thickness (Tb.Th). When IR was combined with HU, BV/TV decreased by another 5%. These results indicate that HU and IR were not clearly additive in this experiment. Among the parameters analyzed, IR only induced changes in Tb.Th and Tb.Sp. Unlike reports by others, there were no significant changes in trabecular number (Tb.N) from any of the treatment groups relative to the sham-irradiated control group. When HU was combined with IR, Tb.Th decreased by 9%. Our results indicate bone loss was caused by a thinning, not a decrease in the number, of existing trabeculae, which expanded the space between trabeculae. The trabeculae contribute to percent bone volume and microarchitectural integrity. Since HU affects the cortical as well as cancellous tissue, we also determined the extent of cortical bone loss. The cortical region (cortical shell) exhibited a decrease in cortical thickness when mice fed the control diet were exposed to HU, either independently or in combination with IR. When mice were fed the DP diet, IR-induced cancellous bone loss was entirely prevented, consistent with the radio-protective results reported in our previous study. DP also protected the tibia when IR was combined with HU, which is a novel finding in this report. The decrease in trabecular thickness incurred by HU and HU + IR was entirely prevented by consumption of the DP diet. The DP diet also protected from HU-induced decrease in cortical thickness. Unlike the proximal tibia, the distal tibia did not show changes in cortical structure. In contrast, in the proximal tibia HU and IR together, not each treatment alone, caused a decrease in cortical thickness of the proximal tibia. This finding suggests that DP diet cannot fully prevent from all aspects of bone structural deficits induced by simulated spaceflight. In order to confirm our results, we examined another skeletal site, the vertebra, which is a representative axial bone. Under conditions of simulated weightlessness and consumption of control diet, BV/TV and Tt.Tb.Th of the vertebral body were reduced accompanied by a reduction in cortical thickness and cortical bone area. Collectively, these findings indicate an overall deterioration of bone via thinning of the vertebrae's trabeculae and cortical tissue. This deterioration of the microarchitecture directly impacted the overall strength of the tissue, as reflected in the decrease in maximum load tolerable by the vertebral body, as well as the decrease in materi

Technology Maturity (TRL)

Start: **3**
Current: **4**
Estimated End: **4**



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  └ TX06.3 Human Health and Performance
    └ TX06.3.2 Prevention and Countermeasures

Target Destinations

The Moon, Mars

Stories

Articles in Other Journals or Periodicals
(https://techport.nasa.gov/file/60835)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/60834)

Project Website:

https://taskbook.nasaprs.com